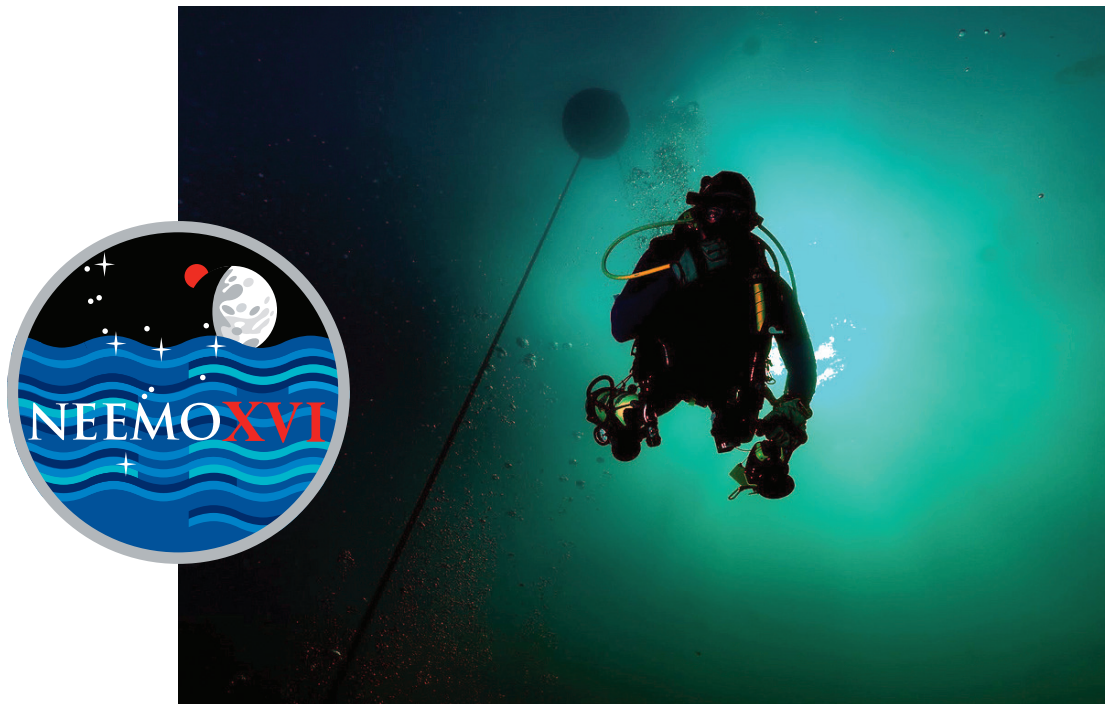


NASA Extreme Environment Mission Operations Project (NEEMO) 16

NASAfacts



Background

NASA is actively planning to expand the horizons of human space exploration, and with the Space Launch System and the Orion crew vehicle, humans will soon have the ability to travel beyond low Earth orbit. That opens up a solar system of possibilities, and NASA's goal is to send humans to explore an asteroid by 2025. But to accomplish that goal, the work must start now.

NASA is developing the technologies and systems to transport explorers to multiple destinations, each with its own unique – and extreme – space environment. Future destinations may include near-Earth asteroids, the moon, and Mars and its moons.

Analog missions help NASA prepare for human missions to these extreme-environment destinations. Analog missions are field tests conducted here on Earth in remote locations that are identified based on their environmental similarities to a target destination. Analogs allow NASA astronauts, engineers and scientists to work with representatives from other government agencies, academia and industry to gather requirements, test operational concepts and develop the technologies necessary to ensure an efficient, effective and sustainable future for human space exploration.

The NASA Extreme Environment Mission Operations project, known as NEEMO, sends groups of astronauts, engineers



and scientists to live in an underwater habitat for up to three weeks at a time. These crew members, called aquanauts, live in the world's only undersea laboratory, the National Oceanic and Atmospheric Administration's (NOAA) Aquarius Reef Base located 2.7 miles southeast of Key Largo, Fla.

NEEMO missions are performed at Aquarius because the isolation, constrained habitat and crew quarters, harsh environment and reduced gravity challenge aquanauts to perform mission operations despite extremely formidable conditions. Much like space, the undersea world is a hostile, alien place for humans to live. NEEMO crew members experience some of the same challenges there that they would on a distant asteroid, planet or moon.

NEEMO 16

The NEEMO 16 objectives focus on asteroid mission scenarios, but the operational and technical concepts that the team is investigating are common to any long-duration human exploration mission:

- What techniques for anchoring and performing mission operations will be most effective for exploration of an asteroid?
- What robotic systems will best optimize crew activities?
- How will Earth-bound mission control centers communicate with the crew?
- How many crew members are needed to explore a deep space destination such as an asteroid? Would Apollo's three-person crews be sufficient, or should an extra person or two be added?

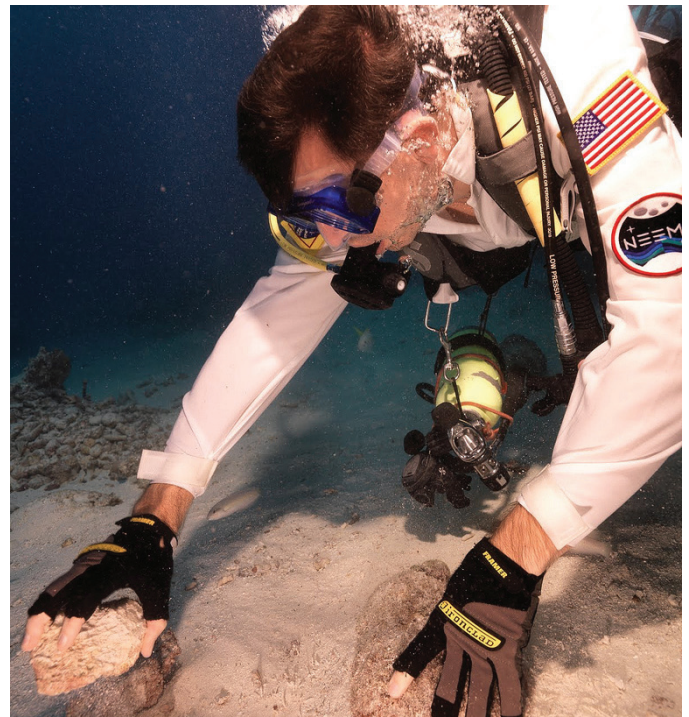
- How should mission activities be distributed among crew members upon reaching the asteroid?
- What effects will time delays in communications have on mission operations and the crew's behavioral health?

Testing these mission concepts in the weightless underwater environment helps NASA understand the challenges of sending humans to explore an asteroid. Long-duration NEEMO missions provide astronauts with a realistic approximation of situations they will likely encounter on missions in deep space and provide an understanding of how to carry out daily operations in a simulated planetary environment.

NEEMO 16 Aquanaut Crew

An international crew of four will spend 10 days in Aquarius. Dottie Metcalf-Lindenburger, a NASA astronaut, will lead the crew as NEEMO 16's commander. Metcalf-Lindenburger was a mission specialist on the STS-131 mission of space shuttle Discovery. Kimiya Yui is an astronaut for the Japan Aerospace Exploration Agency and was a member of the 2009 astronaut class. Timothy Peake of the European Space Agency also is a member of the 2009 astronaut class. Rounding out the crew will be Cornell University Professor Steven Squyres.

The NEEMO 16 mission will evaluate a variety of crew size and distribution scenarios as they live and work underwater to determine the most efficient way for humans to explore an asteroid.



AREAS OF STUDY FOR NEEMO 16

Restraint and Translation Techniques

Human missions to an asteroid present unique challenges, such as performing mission operations in microgravity. Even the largest asteroids do not have enough gravity to allow astronauts to safely land or walk on them, and some of them could even be rotating piles of rubble. A human mission to an asteroid will require technologies that allow astronauts to approach an asteroid, examine it closely and take samples and measurements, all while floating beside the surface. Anchoring a spacecraft or spacesuits could provide a safe way to explore an asteroid, but the variety of asteroid sizes, rotation rates and compositions makes designing and operating an anchor another challenge.

The microgravity environment of the sea floor allows NASA to begin to understand the integrated spacewalk operations associated with asteroid exploration, including translation, restraint and anchoring techniques, along with the sampling tools and deployment of various instrumentation packages. Translation aids, including an excursion line device, hand-over-hand tethers, a deployable boom and jet packs will be evaluated to determine the operational implications of different anchoring strategies. The results from these tests, combined with robotic precursor missions, will enable engineers to develop anchoring techniques, eventually leading to a solution for how to securely anchor to an asteroid.



- **Anchors:** Astronauts could anchor themselves to the surface of the asteroid (the type of anchor used would depend on the asteroid being explored) to stay in place and string lines between several anchors to travel between closely spaced points.
- **Booms:** On the International Space Station, spacewalkers often use the 58-foot-long Canadarm2 robotic arm to move from site to site on the station's exterior. A boom on the concept Space Exploration Vehicle could perform a similar function, flying astronauts around the asteroid's surface for closer inspection.
- **Jet Packs:** To explore the asteroid, an astronaut could fly around with a jetpack, similar to the SAFER – Simplified Aide for EVA Rescue – or Manned Maneuvering Units that have been worn on space shuttle and space station spacewalks. An underwater scuba diver propulsion vehicle will be used to test this concept during NEEMO 16.

Communications

An asteroid mission requires extensive travel time, during which the crew will be in cramped quarters with significantly delayed communications with Earth and no chance of rescue in the event of an emergency. During the NEEMO 16 mission, the aquanauts will live and work in similarly cramped quarters, operating under isolated conditions, including an imposed 50-second communications delay from mission control. From this mission, NASA can learn more about how time delays affect communications with mission control and the science team, in addition to learning how well the crew operates when they are required to be more self sufficient.

Additionally, a behavioral health and performance study will examine the impacts of communication delays on the crew's performance. Results will be used to develop procedures for a future communications delay test on the International Space Station.

NEEMO MISSION COMPONENTS

Aquarius

Aquarius Reef Base is owned by NOAA and operated by the University of North Carolina at Wilmington via the National Undersea Research Center in Key Largo. The laboratory is located in the Florida Keys National Marine Sanctuary and is on the ocean floor next to deep coral reefs, 63 feet below the surface.

The Aquarius system has three elements: a life-support buoy at the surface, the habitat module and a base plate that secures the habitat to the ocean floor. The Aquarius habitat has about 400 square feet of living and laboratory space. This size is similar to that of the Zvezda service module of the International Space Station, which has served as the living quarters for space station crew members.

A technique known as saturation diving allows divers to live and work underwater for days or weeks at a time. After 24 hours underwater at any depth, the human body becomes saturated with dissolved gas. With saturation diving, divers can accurately predict exactly how much time they need to decompress before

returning to the surface. This information limits the risk of decompression sickness. By living in the Aquarius habitat and working at the same depth on the ocean floor, NEEMO crews are able to remain underwater for the duration of their mission.

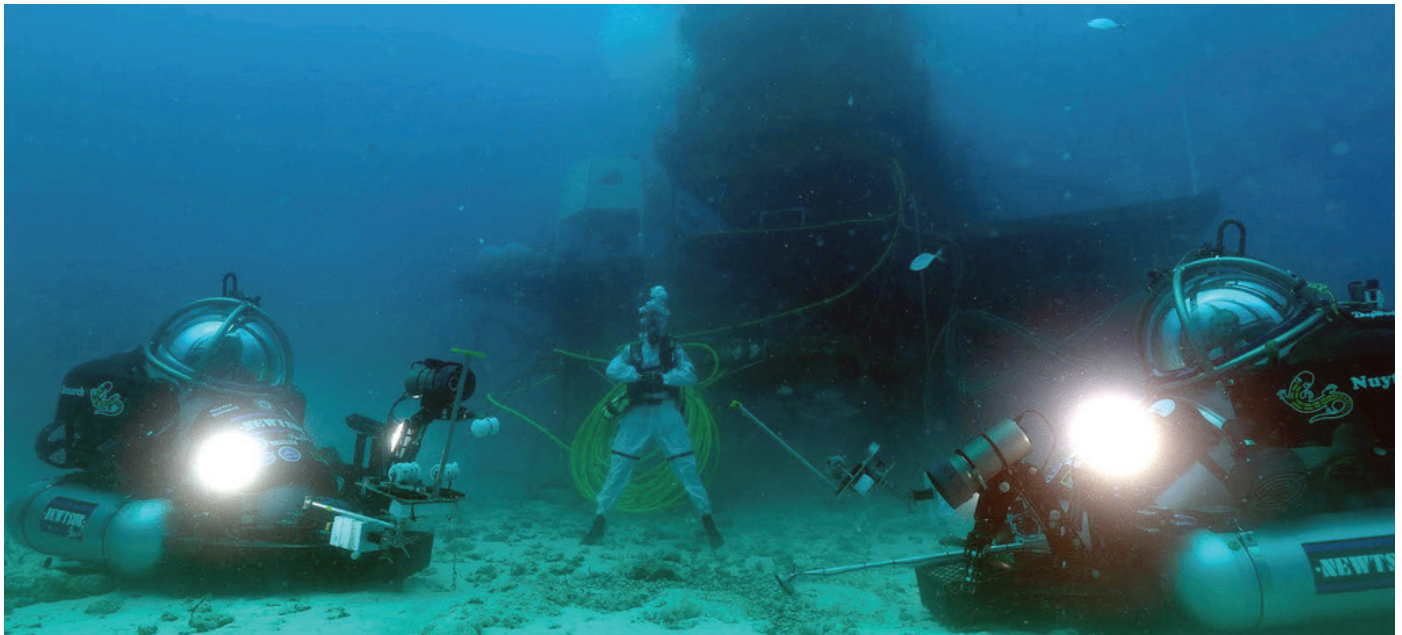
Mobile Mission Control Center

While the aquanauts have Aquarius as a home away from home during their exploration activities, the ground support, data management, science and mission control teams need a home as well. The Mobile Mission Control Center provides that home for most of NASA's exploration analog activities and provides support for science operations; video switching, storage and retrieval; networking (including wireless, cell routing and delay simulation); command teams; weather protection and the all-important air-conditioned refuge from the Key Largo heat.

DeepWorker Submersibles

The DeepWorker is a one-person submarine, which will stand in as an underwater version of NASA's concept Space Exploration Vehicle, which might someday be used to explore the surface of an asteroid.

The NEEMO 16 science team will operate the DeepWorker Submersibles, collecting samples and interacting with crew members performing simulated spacewalks during the mission.



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